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INTEGRATING INFORMATIONAL, SOCIAL, AND BEHAVIORAL EXCHANGES BETWEEN HUMANS, URBAN CENTERS, AND THE INTERNET

by

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The United States Navy is experiencing a change in ship operations due to widespread interest in accessing the web and Internet. Security is a key concern. Communications technology may improve operations, reduce manning while not impacting readiness, increase the effectiveness of smaller crews, and enable more efficient handling of fires and other emergencies. This thesis explored the means of integrating operations, crew, and technology in the context of a ship by modeling and evaluating a model of integration for businesses, consumers, and the Internet, in the context of a city. As with Internet usage in civilian circumstances, naval personnel on deployment desire and use access to the Internet and the web. This thesis provides insights into the integration of the Internet, urban centers, and people through a system of systems perspective. This research established the boundaries of each system; identified the interactions needed to integrate the three components; and addressed how this integration may be achieved. The findings provide researchers and organizations a model for investigating measures of effectiveness for linking business models with customers and offers insights into possible future ship operations.

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INTEGRATING INFORMATIONAL, SOCIAL, AND BEHAVIORAL EXCHANGES BETWEEN HUMANS, URBAN CENTERS, AND THE INTERNET

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ABSTRACT

The United States Navy is experiencing a change in ship operations due to widespread interest in accessing the web and Internet. Security is a key concern. Communications technology may improve operations, reduce manning while not impacting readiness, increase the effectiveness of smaller crews, and enable more efficient handling of fires and other emergencies. This thesis explored the means of integrating operations, crew, and technology in the context of a ship by modeling and evaluating a model of integration for businesses, consumers, and the Internet, in the context of a city. As with Internet usage in civilian circumstances, naval personnel on deployment desire and use access to the Internet and the web. This thesis provides insights into the integration of the Internet, urban centers, and people through a system of systems perspective. This research established the boundaries of each system; identified the interactions needed to integrate the three components; and addressed how this integration can be achieved. The findings provide researchers and organizations a model for investigating measures of effectiveness for linking business models with customers and offers insights into possible future ship operations.

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LIST OF ACRONYMS AND ABBREVIATIONS

ACS	American Community Survey
BLS	Bureau of Labor and Statistics
CAS	complex adaptive system
EMMI	energy, matter, material wealth, information
MOE	measure of effectiveness
O&I	organizations and institutions
PDC	production-distribution-consumption
POS	point-of-sale
SEO&I	society, environment, organizations and institutions
SET	social exchange theory
SoS	system of systems
TRA	theory of reasoned action

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EXECUTIVE SUMMARY

The United States Navy is trending toward reduce crew sizes on ships. The more changes in technology and ship design and architecture are helping to fuel interests in smaller ships. Yet, the use of modern communications technology has not only not kept pace, but it has hindered operations, readiness, reduced effectiveness in handling of fires and other emergencies. In particular, the ready access to web-enabled texting, chat, and voice communications is thwarting efficient and effective operations. This thesis explored the means of integrating ship operations, crew, and technology by modeling and evaluating a model of integration for businesses, consumers, and the Internet. In the context of a city, this research investigated the measures that may help determine if ubiquitous communications results in more effective use of ship's crew regardless of size of ship.

There is a significant need to integrate businesses, consumers, and the Internet, effectively, in the context of a city. From the mid-1990s to the present, Internet usage has grown significantly. Pew Internet research indicates that internet adoption rates have increased from a mere 14% in 1995 to over 80% in 2013. Over 70% of individuals online look for information about a product, buy a product, participate in social media, or research hobbies. Prior to the Internet, these behaviors were solely enacted within the physical bounds of an urban center- mall, outdoor shopping plaza, or downtown, to name a few. The Internet has enabled the exhibition of these behaviors without the people who access the internet leaving their home. This thesis investigated the integration of the Internet, urban centers, and people through a system of systems perspective.

The inquiry established a fundamental background based on social exchange theory and the theory of reasoned action. These social theories provide insight into the cognitive processes by which humans respond to influences, and thus behave. A social foundation is necessary because cities are composed of people acting by an assumed rational nature. Every component of the city involves some form of human action, as cities were developed to support human livelihood. The inquiry explored the historical evolution of cities to identify forms that are self-similar and repeatable throughout every level of city aggregation. Three specific self-similar and repeatable forms were identified

to be society, environment, and organizations and institutions. These three forms established the most basic elements of a fractal in the context of a city. The interaction of these elements enacts fractal-level functions, with consequential fractal-level outputs. The interaction of fractals was shown to occur through the exchange of energy, matter, monetary wealth, and information. The interaction of fractals results in city-level behavior. The development of a city fractal model was shown to be useful in simulating hypothesized courses of action, such as policy changes, new real estate development, and modifications to the consumer market. MOEs were established to identify areas where cities could be more productive, and used to assess potential modifications to the city.

Social exchange theory (SET) established a framework through which to assess human behavior. SET focuses on the actions of an individual, based on the reactions of secondary individual(s). The basis upon which humans decide to act is described through Homans's propositions: success proposition, stimulus proposition, deprivation-satiation proposition, and value proposition (Homans 1974). The theory of reasoned action (TRA) indicated that human action is also based upon individual beliefs, normative beliefs, and the influences of previous behaviors on those beliefs. A refined model of TRA was developed to indicate the interactions that result in the formulation of individual and normative beliefs, as well as the addition of consequences to previous actions, which influence the development of both types of beliefs.

Cities were shown to be composed of individuals, environment, and organizations and institutions (SEO&I) (Warren 1963 and Blanchard and Fabrycky 2011) who carry out their respective businesses. O&I is composed of public, private, and circulation components (Nolen 1922). City planning is the effective integration of these components to enact city functions, plans, and is realized in physical design. City functions are: production-distribution-consumption, socialization, social control, social participation, and mutual support (Warren 1963). The integration of SEO&I realizes city functions (Warren 1963). The ability of these functions to execute within the domain of a business represents the systemic view of that business. In other words, a business is a system *if* all of the elements of the business depend on each other to interoperate to fulfill all of the business functions. Interoperability includes systems, processes, procedures,

organizations, and business goals (termed “missions” for DOD) and must be balanced with information assurance (Chairman of the Joint Chiefs of Staff. 2008.). The strategy for information assurance is to maintain stability and agility (termed “stagility,” Langford 2013). In essence, the ability of systems or system of systems to provide whatever is needed and when needed spans the requirements for communicating and acting on that communication in an appropriate manner. Interoperability requires connectivity, coupling, and cohesion (Langford 2012).

The composition of SEO&I at the aggregate-city level was shown to be a self-similar composition at the housing unit level, the most basic building block of a city (Batty and Longley 1994). The accumulation of housing units is a neighborhood, neighborhoods a district, and districts a city. Each level of hierarchy, with respect to the neighborhood, exhibits SEO&I in self-similar and repeatable forms. The neighborhood exhibits a group of individuals (combined residents), combined household structures (O&I), and the combined geographical extent (environment). The interactions of SEO&I, at every level of aggregation, realizes functions pertinent to the subject level of aggregation. This same self-similar and repeatable form is observed in businesses, government agencies, military personnel deployed on ships, and transportation systems at every level of city aggregation.

The aggregation of self-similar forms within the context of a city indicates that the city is composed of fractals based on SEO&I. Nikos Salingaros introduced the concept of fractal organization as the keynote speaker at the 5th Biennial of towns and town planners in Barcelona Spain (Salingaros 2003). As described by Salingaros, fractals combine structure and hierarchy. As defined, structures are of a certain size and to add or subtract substructure is to create fractals. Removing the fractal nature of a structure means to eliminate the interactions in the “broken” structures, thereby eliminating systemic interactions between people or reducing the density of objects, i.e., buildings. Further, fractals carry certain attributes (Langford 2012) as are part of the affinity groupings that create the living spaces in which characterize culture and social interaction. Foundational to thinking of cities as fractal entities is the notion of scalability, connection, mutual support, and like-kindness and natural attraction.

Therefore, it is the nature of a system or system of systems to have an essential, intrinsic attribute that is describable through fractals.

The fractal nature of the city indicates that a standardized, executable model can be developed to assess the performance of city functions at every level of aggregation, following the premises and integrative framework of the general theory of integration (Langford 2013). The assessment capability reaches into the most minute city fractal, giving businesses the ability to assess market reach, penetration, and profitability projections. Government agencies can use the fractal model to identify the implications of policy changes and city modifications, through simulation. To delve more into the interoperability issues of an organization’s fractal model more research recommended and is needed to collect data of fractal interactions, integrating the data into an executable model, and developing a standardized framework for the model. Such research is beyond the scope of this thesis.

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I. INTRODUCTION

Every day a seeming infinite number of interactions occur within the context of a city. Humans, buildings, vehicles, roads, businesses, and many other objects of interaction combine to form the notion and activities of a city. Each of these objects may, in actuality, be a system. The human system is composed of numerous interacting objects such as organs, bones, and muscles, which interact to provide human level functions. Likewise, the interaction of city's systems provides city-level functions. Systems acting together for mutual benefit combine to for the city—a system of systems (SoS). Two functions of the city are to expand physically and to prosper economically. Expansion is an indication of a "successful" city. Economic prosperity is a consequence of a "successful" city. Two problems are faced in the fulfillment of these functions in the modern age of technology. First, demographic data collection methodologies, such as the American Community Survey and the American Housing Survey, are too slow in time from collection of data to use of data and lack sufficient detail to display the complexities of interactions. Therefore, data with latency and data that lacks proper causal relations with activities inhibits cities and businesses from responding to timely and effective decisions. Second, online consumerism has curbed patronage to brick-and-mortar stores. The solution to these problems is in integrating and creating the requisite interoperability of informational, social, and behavioral exchanges between humans, urban centers, and the Internet.

Physical expansion of the city infers not only increasing the three-dimensional spherical circumference of the city's physical boundaries, but also includes increasing the volumetric density of the city. Both boundaries and density are representable in terms of a fractal model. Volumetric density has two-fold dimensionality: density of structures and population density. Physical expansion of the city challenges city planners and real estate developers as they attempt to leverage the growth and uses of city spaces in a way that is beneficial to the city, residents, and business functions. Leveraging growth requires information on how the city is expanding, the directions in which it is expanding, the rate of expansion, why it is expanding, and what is expanding.

The challenges of this expansion are compounded by the interpretation of the city as simultaneously a SoS and as a political entity. The SoS perspective creates a symbiotic relation between the systemic parts of the city (including businesses, residents, and tourists) as members of each group interact—in contrast to the disparate views driven by political agendas and political posturing. Interactions of the political kind position and realign these same groups into new affinity grouping that often cross their traditional boundaries. Sometimes these new formulations of groupings are seemingly tangential to their original groupings. Gathering data on these realignments and formulations is a perennial task that challenges better collection and analysis of social data. Expansion tends to blur the rather traditional lines of demarcation between the original groupings and fosters new segmentations. It is these new segmentations and affinity mappings that become the normative factor for the online community. Each reformulation builds new fractal structures.

The successes and failures of the economic system can be indicated by selecting appropriate measures and formulating applicable metrics. Real estate developers and brick-and-mortar storefronts currently rely on demographic information to identify the primary/secondary market areas, target audience, competitors, and supply/demand forces for specific products. Much of this information is gathered by the Bureau of Labor and Statistics (BLS), Census Bureau, private market analysis companies, and corporate agents collecting data through first-hand observations. Identifying the new normative factors for the online economy is a key determinant for reaching and selling to city customers.

The American Community Survey (ACS) has one of the faster turnaround rates, from sample to report, for demographic products from the government agencies. ACS takes monthly samples of housing units over the course of five years to establish a small-area foundation of data. After the foundation is established, it is updated annually. (U.S. Census Bureau 2009) Other products from these agencies, such as the Decennial Census, Annual Economic Survey, and Population Estimates Program, can take up to 10 years to manifest. Most releases of data lag collection by 2–3 years. The delay in presenting detailed data is problematic for the modern era, in which humans are exposed to ever increasing amounts of stimuli. Stimuli such as social media and fast-paced evolution of

technology encourage human behavior to tend toward instantaneous satisfaction. It is understandable for governmental agencies to fall behind in providing relevant, timely data given their cumbersome approaches and methods. As such, businesses need to collect their own data and develop relevant information on consumer behavior, needs, and wants to keep up with the changes ideas in order to capitalize on the latest opportunities, trends, and whims. Businesses and cities in general have been at the mercy of slow statistical data collection. The implantation of the integrated domain of humans, urban centers, and the internet has the potential to improve the efficiency of collecting data, disambiguating the affinity groupings and analysis to keep up with changing markets.

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II. METHODOLOGY

Each component— human, urban center, and Internet— is considered a system in the general sense. Each system is decomposed into its interior objects of interaction, boundaries, and mechanisms of interaction with the other systems. The human is a social entity and assumed rational. The theories of social exchange theory and theory of reasoned action are utilized to reveal the cognitive processes of human behavior. These processes identify the ways by which human behavior can be stimulated and responded to. Cognitive processes also reveal how to measure the effectiveness of the proposed integrated system, and whether or not a behavior has indeed been altered.

Urban centers, or cities, are decomposed into various interacting systems that make up the aggregated city. Each system has a multitude of functions and is incorporated into city-level functionality. This perspective is important in identifying how the human interacts with the city, and vice-versa. Also, by viewing the city as a SoS, a dynamic model can be created as a tool to improve city functionality and planning efforts. The reader is referred to an in-depth discussion of system and system of systems (Langford 2012).

The integrated system is then detailed, showing interactions with each of the systems previously discussed. Data collection and measures of effectiveness are then discussed to identify the benefits of using the system. Data from the integrated system can also be implemented into the city's dynamic model and indicate the current behavior of the city.

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III. BACKGROUND

A. HUMANS

1. Social Exchange Theory

Social exchange theory (SET) is best described not as a theory, but, as a frame of reference. It is a framework that enables social theories to relate to one another, whether in opposition or cooperation. Peter Blau describes the scope condition for SET as this: "Social exchange as here conceived is limited to actions that are contingent on rewarding reactions from others" (Blau 1964 and Emerson 1976, 336).

SET focuses on societal actions and reciprocated reactions, which requires the existence of sources (objects) by which actions are enacted. Because SET is a social theory, objects refer to humans. However, objects can take on numerous forms. This thesis focuses on objects such as: smartphones, retail stores, and cities. More broadly, "objects are comprised of matter or energy in ways that manifest as physical properties" (Langford 2012). Each object is identified as unique and independent from other objects through the establishment of physical, behavioral, and functional boundaries. Physical boundaries define the extent of the object's spatial and tangible properties. A human is physically bounded by the skin, beyond which the subject ceases to physically exist. The skin marks the outer edges of the spatial dimension and tangibility to which the human is confined. The human body is composed of multiple sub-objects: brain, muscles, nerves, and bones. The interaction of these sub-objects results in actions, which are human functions. For example, human functions are "to stand," "to walk," and "to reach." Functions are observable and measurable. In this case, "to stand" can be measured by duration, "to walk" by speed, and "to reach" by distance. Each of these functions is enabled by the transfer of EMMI between sub-objects. For instance, the brain sends an electrical signal (information and energy) to the muscle. In response, the muscle contracts transferring energy to the bone, by which the bone is moved toward or away from the body. The extent to which sub-object interaction results in action forms the functional boundary of the aggregate human object. The behavioral boundary is realized when the

enactment, or cessation, of a human function is influenced by EMMI from an external source. A human might enact the function “to walk” in response to the illumination (energy transmittance) of a pedestrian walk signal. In this case, the behavioral boundary exists in that the pedestrian signal enticed the human to walk. If the pedestrian signal were to indicate “stop” and the human ceased walking, then again the behavioral boundary is observed. However, if the human were to continue walking, in spite of an indication to stop, the behavioral boundary would be broken as it has ceased to influence a response from the human. If the human runs, instead of stopping, the behavioral boundary remains intact, because a response was elicited.

The interaction of objects requires the satisfaction of the condition of connectivity. Connectivity infers the transfer of EMMI between the boundaries of the two interacting objects. In order for the reaction to be associated with and dependent upon the initiating action, awareness and acknowledgement (active or passive) are required of the receiving object. Acknowledgement of the reception of EMMI is observed from within the receiving object’s change in EMMI. That is the receiving object is aware that its contents of EMMI have changed (Langford 2012). Awareness may or may not be observable or measurable, that is conscious to a human observer, in all circumstances. Only when these conditions have been met, can the initiating action and subsequent reaction be considered associated and reciprocating, which establishes the fundamental basis and boundaries of SET. In reference to the earlier mentioned scenario of the pedestrian crossing the street, the pedestrian is aware of the transfer of energy (the illuminated signal) because his or her eye captured the energy. The eye, by itself, is aware that it has captured electromagnetic energy, even though the brain (more specifically, human consciousness) has not realized it yet. The eye’s awareness is realized by the subject, when the eye transmits the image to the brain, subsequently bringing the image into the consciousness of the individual. Herein, it is observed that an interaction between the aggregate human object and the pedestrian signal occurs, even if the individual is not conscious of the interaction. A lack of consciousness that eyeball-awareness occurred would infer a problem in the function of the eye to transmit the image, or the function in

the brain to receive the information. It would not infer that the interaction between the eyeball and pedestrian signal did not occur.

SET claims that the actions of an object are causation for reaction by a separate object. Without causation, social exchange does not occur. SET's action and reaction infers interaction, and more specifically an exchange in EMMI. Exchanges in EMMI relate to functions, which, when caused by influential, outsourced stimuli, become behaviors. Such is the premise for the Operant Format, which is "the study of the effective use of social power in controlling behavior" (Emerson 1976, 338). In the case of Homans's pigeon experiment, the pigeon, as an object, has inherent functions: to stand, to walk, to peck. The pigeon has the ability to perform these functions in absence of any external stimuli; however, once these functions are enacted in response to an influential stimulus, they become a behavior. The second object in this scenario is a disc. The function of the disc is to be pecked. The disc's function is measured by how many times it is pecked, the specification is five times. The second measurement is time between pecks, the specification is a relatively short time. When the disc's first specification is fulfilled (pecked five times) a piece of grain is provided, this is the schedule of reinforcement. Upon receiving the grain, the pigeon is encouraged to reiterate the exchanges of EMMI (actions, and therefore functions), that resulted in receiving grain. The first time the pigeon engages in this sequence, there is no behavior, because there was no influential EMMI to encourage the pigeon to peck. The second and subsequent iterations of the pattern are behavioral, because there is an expectation of receiving grain. That is, the first reception of grain influenced the pigeon to re-enact the function "to peck." By continuing to provide the reinforcing stimulus, for every five pecks, the experimenter lures the pigeon into a dependent exchange relationship, wherein the experimenter gains power over the pigeon. If the schedule of reinforcement is increased to seven pecks per grain, the experimenter gains more power over the pigeon. The schedule of reinforcement can continue to increase until the pigeon continues to peck without receiving grain. At which point the pigeon's behavior has been permanently altered, without receiving a single new stimulus, wherein the behavioral boundary is based upon a historical influence of EMMI and perpetuates into the future (Emerson

1976). This is the ideal scenario for marketing agencies to capture a consumer with an advertisement, cause the consumer to buy the product, and keep the consumer buying the product, even in the absence of advertisements.

In relation to humans, Homans presented a few propositions for the consideration of why humans act (1974). The Success Proposition indicates that human action is based upon rewards that particular action has gained them in the past. More specifically, the Value Proposition argues that human action is based upon perceived value of the resulting effect of that action. The Rationality Proposition combines perceived value of an action with the probability of it occurring favorably. A human will enact whichever alternative action has the higher multiplicative product of value and its associated probability. Quite simply, these propositions infer that humans will take the course of action that is perceived to be the most beneficial. In the case of the pigeon, it was perceived beneficial to peck, because previous pecks resulted in grain and no harm, or other misfortune, was received as a result of those actions. However, the Deprivation-Satiation Proposition confers that the more often a human receives the same (or similar) reward, the less valuable it becomes (Homans 1974).

The Stimulus Proposition argues that if under a certain set of circumstances, a human was favorably rewarded for their action, then in a separate, yet similarly perceived circumstance, the person is more likely to perform the same (or similar) action as before. The Stimulus Proposition means that the circumstances responsible for stimulating action do not need to be the same as before, such as in the pigeon experiment, but may be perceived similar. This proposition is important in advertising. If a particular advertisement has achieved success in altering a person's behavior, then an independent advertisement, that is perceived similar to the first, can be expected to receive a similar response from the consumer (Homans 1974). In light of the Deprivation-Satiation Proposition, the consumer must not only be met by a similar stimulus, but also must perceive that responding is valuable. It is therefore not enough to attempt influence the consumer to act through some stimulus (advertisement or coupon), but to ensure the consumer continues to perceive that value is added to them by responding to the stimulus.

The perception of value can be measured by the receiving and responsive object. Take for instance an automobile fuel station. The station attempts to stimulate the behavioral action of vehicle-borne consumer by: 1) having an observable physical presence of the building and fuel pumps, 2) advertising the cost of fuel on a display, and 3) soliciting the brand name of the fuel. Each stimulus involves the projection of energy and information toward the consumer. The rational consumer has three options: stop at this particular station for gas, go to another station, or not get gas anywhere that day. Each instance has its own measures. The first measure is how much remaining fuel the consumer has. Secondly, how long the remaining fuel is expected to last in distance, time, or number of round trips between home and work. The third measure is the current cost of fuel at this location and others in close proximity. The last measure is how long it takes to complete the fueling process, from driving in to driving out. The majority value in fueling is determined at the point where the consumer's benefits (not running out of fuel, mobility, convenience) outweighs the costs (cost of fuel, time, finding another station) incurred.

2. Theory of Reasoned Action

The Theory of Reasoned Action (TRA) builds upon the concepts of SET. TRA focuses on the cognitive processes and reinforcements that result in human behavior. TRA identifies behavior as "observable acts of the subject," which coincides with the previous discussion on actions (Fishbein and Ajzen 1975). Further references to TRA will utilize the term action, vice behavior, to maintain continuity of terminology. Behavior will continue to reference responsive action due to influential EMMI.

TRA recognizes two parallel pathways that result in a human's intention to act and subsequently act, as illustrated in Figure 1. The first pathway involves forming a belief about the consequence of performing a specific action. This is followed by the formation of an attitude towards performing the act. The second pathway begins the formation of normative beliefs about the intended act, which creates a subjective norm pertaining to the intended act. The human's cognitive perception of their own attitude and subjective norm concerning the act forms the human's intention to act. Intention to act is

followed by acting or not, but entirely dependent on the resultant intention. The action and the resultant consequences influence the subject's beliefs and normative beliefs about the action (Fishbein and Ajzen 1975). However, this model is incomplete in that it does not account for the consequences of actions, and how those consequences influence individual beliefs and normative beliefs. The TRA model is revised in the discussion following and illustrated in Figure 2.

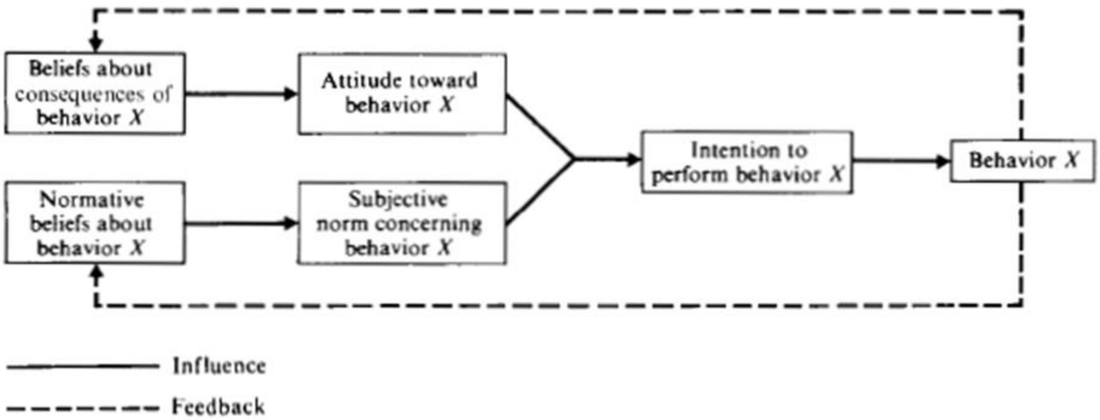

Figure 1. Theory of Reasoned Action Model (from Fishbein and Ajzen 1975)

Beliefs, in the first pathway, represent the knowledge of information the subject human has about the object, in the context of an action, in question. Beliefs are based upon the attributes of an object in the context of an action. An attribute is a quantifiable or qualitative measure and measurement of performance of an object's function. Beliefs about an object, in the context of an action, are the "basis for the formation of an attitude towards the object," in the context of an action (Fishbein and Ajzen 1975).

In the earlier described scenario of a consumer contemplating fueling their vehicle, the belief is a projection of expectations the consumer has about performing the action of fueling their car. The belief is triggered by an interaction between the consumer and the fuel station that influenced the consumer to consider fueling his car. Because the belief is about an action that has not occurred, the consumer must have cognition of an independent interaction that is either the same, similar, or reminds the consumer of the action in question. The consumer's assessment of the independent interaction directly

impacts the formation of their attitude toward presently fueling their car. Homan's propositions will take effect in the formation of the consumer's attitude. For instance, if the consumer recalls they had a previous experience fueling their car at that particular station (same interaction) and it was satisfactory, then they have reason to believe that satisfaction will be gained again. If the consumer has not previously fueled a car at that particular station, but at another station in close proximity (similar interaction) then the consumer will assess their expected experience based on their similar experience. Lastly, if the observance of the fuel station reminded the consumer of a favorable childhood experience, perhaps buying ice cream at a fuel station (reminded interaction), then the consumer may form his belief on the reminded experience, rather than on an experience of fueling his car at any station. The formation of the belief may involve as many or as little, minimum of one, types of interaction that the consumer has been subjected to in the past.

As noticed in the car fueling example, beliefs require an initiating interaction. An interaction must occur that forces the human to form a belief about a responding action. The individual draws information from previous, independent interactions such as: what action should be realized, the expected costs, and the expected benefits. The information gathered is utilized to form an attitude concerning the responsive action. Attitude is based on the assessment of the collected information and results in a determination to perceive the responsive action as favorable, or not.

The determination of plausibility and access follow the assignment of an attitude toward the responsive action. Plausibility infers the fulfillment of three characteristics: reasonable, valid, and truthful. The human must assess whether the beliefs and attitude toward the action, and consequences, under scrutiny has been subjected to sound judgment, strongly founded in logic, and is based on reality or actuality of the same or similar actions. Access refers to the "right to enter…to obtain or make use of or take advantage of something" (WordWeb7 2013). It infers the ability of the individual to enact the action in question. This assessment flows directly into the formation of the intention to act.

The second pathway begins with the establishment of Normative Beliefs. Fishbein and Ajzen define these beliefs as, “beliefs that certain referents think the person should or should not perform the [action] in question” (Fishbein and Ajzen 1975). However, the term referents should not be so limiting to infer only other humans. Referents has a much broader application in that it also refers to laws, rules, policy, culture, religion, and others of the like. These elements establish a model by which human action should be conducted. The realization of normative beliefs is consequential to interactions of objects which have the authority to establish such standards. The interactions of business executives and lawyers result in business policies.

The Subjective Norm is based upon the influences of Normative Beliefs, but is subject to the motivation of the relevant society to comply with Normative Beliefs. The Subjective Norm is the collective beliefs of influential others that impact how one chooses to act. They are based on Normative Beliefs, but may not be a direct implementation of them (Fishbein and Ajzen 1975). For instance, a business policy (Normative Belief) may be to greet every customer who walks into the store. However, the general consensus of the store employees may be that greeting every customer is overburdening due to the significant number of customers who enter the store every day. The socially accepted modification to the policy may then be to greet every other customer instead (Subjective Norm). A new employee will base her intent to act (greet customers) upon her own beliefs of greeting every customer and the Subjective Norm of greeting every other customer. As observed in this example the interaction of employees resulted in the establishment of the Subjective Norm considering the store policy to greet every customer. Therefore, the Subjective Norm is dependent upon the interactions of objects of the moment, which are independent from the objects of interaction that establish Normative Beliefs.

Intention combines the outputs of Plausibility and Access with the Subjective Norm. Intention is the formed anticipation, based on the preceding cognitions, of the desired outcome of the action. Intention includes the probability that the action will be performed. Based on this assessment the action is carried out or not. The action and its resulting consequences stored into the memory of the individual for recollection and

assessment of future actions. The action and consequences are also utilized in the interactions of objects of the moment that establish the Subjective Norm, either to encourage the alteration or continuation of the Subjective Norm.

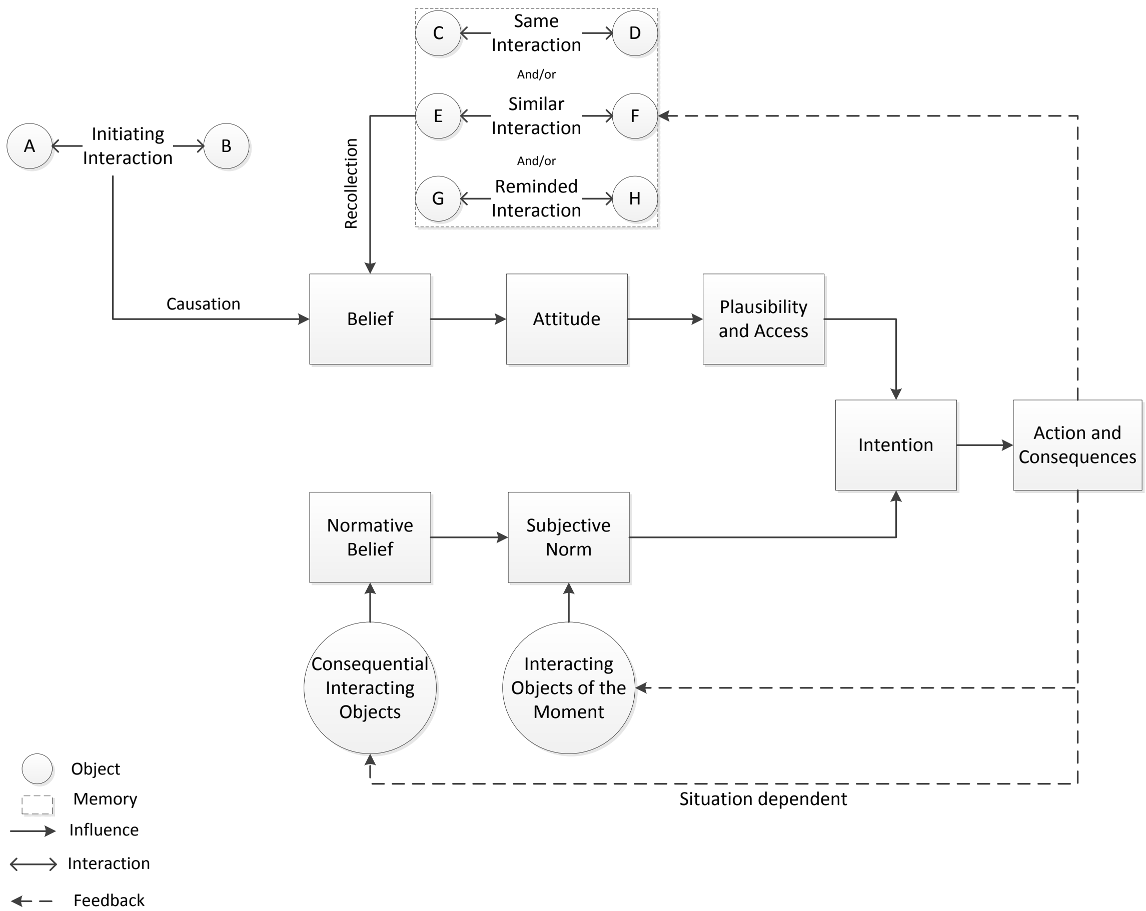

Figure 2. Revised Theory of Reasoned Action Model (after Fishbein and Ajzen 1975)

B. CITIES

1. Definition

For the purpose of this thesis, cities will be considered the smallest government entity within a state. An aggregation of cities is a county, and the aggregation of counties creates the state. A city is a system with physical, functional, and behavioral boundaries resulting from the aggregation of city objects (Batty and Longley 1994 and Langford

2012). The most prominent boundary is the physical boundary which is reflected in the geographical constraints of the local government's jurisdiction. Not only is a city a system, but more specifically it is a system of systems. As a system of systems, the city is composed of interacting systems that exchange EMMI to provide aggregate level functions (Langford 2012). These systems include the environment, individuals, organizations, and institutions (Warren 1963 and Blanchard and Fabrycky 2011). Through the interactions of these systems are the functions of the city realized. The five functions of a city are: production-distribution-consumption, socialization, social control, social participation, and mutual support (Warren 1963).

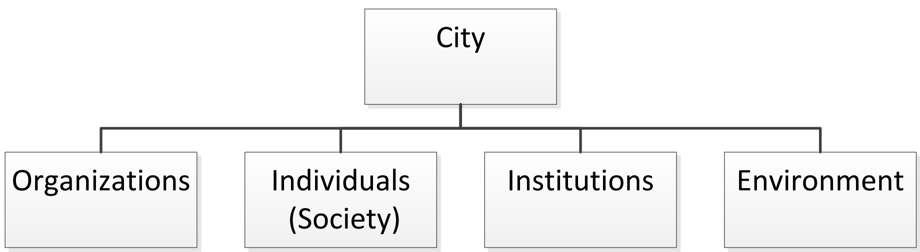

Figure 3. City System of Systems (after Warren 1963 and Blanchard and Fabrycky 2011)

The systems of organizations and institutions are grouped together in this thesis and are decomposed into the following sub-systems: private, circulation, and public (Nolen 1922). The private system encompasses the development and uses of the following types of spaces: retail, office, land, residential, and industrial (Peiser and Hamilton 2012). The public system involves entities of governance, public services, post offices, hospitals, charities, and the like (Nolen 1922). The circulation system entails transportation systems: streets, railways, and waterways (Nolen 1922).

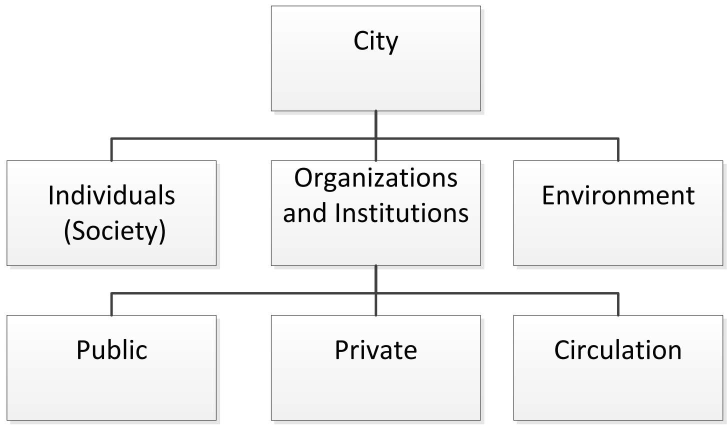

Figure 4. City SoS Revised (after Nolen 1922, Warren 1963, and Blanchard and Fabrycky 2011)

The system of individuals is considered a society (WordWeb7 2013). A society is composed of interacting humans outside the context of a government or business capacity. A human operating on official business is considered to be an object interacting within the system of government (public system) or business (private system), and not in the social system. However, a human interacting within the social system may interact with a business system or government system (as a whole, or in parts as a system of systems), but not as part of both systems simultaneously. For instance, a human, within the social system, may interact with a store in purchasing an item, in which the human will still be considered an object of interaction within the social system. A human that is acting in the capacity of a store clerk is considered an object of the business system and not part of the social system, although they interact, as an agent of the business, with humans that are within the social system. It is best to identify the point of interaction at the point of sale terminal between the consumer and clerk as an interaction between the business system and the social system. The social system includes, but is not limited to, the interactions of friends, neighbors, families, acquaintances, and other interactions of opportunity in a non-official and non-business related capacity (Gehl 2010). Social interactions are described in more detail in Chapter III, Section A.1 on Social Exchange Theory. The social system, as a whole, interacts with all the other systems of the city. Social interactions directly affect the demand and availability of transportation systems, electrical power systems, water supply systems, housing, and the economy, to name a

few. In general, all other systems within the city exist because of the social system. The social system brings purpose, and therefore functions, to the other systems (Gehl 2010).

The environment includes, but is not limited to, interactions of the physical environment with the city such as: precipitation, temperature, atmosphere, terrain, and topography. The environment establishes the physical context in which the city operates (Blanchard and Fabrycky 2011). Environment imposes necessary functions onto the city, such as: to provide shelter from rain, to provide warmth, to control the effects of wind (walls), and to prevent flooding. The environment is an independent and non-controllable limitation, but the functions (to precipitate, to heat, to grow vegetation) of the Earth's environmental system have very significant impacts on the other systems within the city.

The organization and institution system's integration of public, private, and circulation sub-systems realizes functions related to the economy, government, residence, and infrastructure. The circulation system will be considered from here on to be infrastructure. The use of the term infrastructure imposes a modern update to Nolan's description of circulation. Infrastructure includes, but is not limited to, interactions between power cables and power plants, plumbing and water purifiers, rail transit and passengers, and others of similar nature called utilities. Infrastructure enables the transfer of EMMI between, and within, every city system. A particular business, as a system, has a need for the information technology infrastructure to enable effective communication (computer, telephone, mobile technology) within the subject business' boundaries. This same business has the need to communicate, via the information technology infrastructure, with other businesses, governments, and consumers, all of which exist within the boundaries of their own system, external to the subject business system (Neuman and Smith 2010). Further, infrastructure is critical to the order and security of the city. Infrastructure enables the efficient flow of humans through the city via road and highway systems, public transit (rail and bus), privatized transit (taxi, charter bus), and personal transit paths (pedestrian, bicycle). Infrastructure provides utilities such as: electricity, information flow, transportation, gas, water, and waste disposal.

Economic functions involve, but are not limited to, interactions of businesses with other local and non-local businesses, to provide the localized realization, importation,

and/or exportation of goods and services. The economic system is independent from the government system of systems, and is considered a free market. The economic system involves the exchange of goods and services for monetary wealth. It is composed primarily of businesses in the forms of factories, manufacturers, distributors, store fronts, for example. The economic system is the main employer of residents. The continued interaction of the economic system with the social system perpetuates the reciprocal exchange of monetary wealth which is key to enabling residents to provide, for themselves, food, shelter, and clothing.

The government system of systems is a political entity whose function is to provide security, safety, order, and structure to the city. The government system is composed, but not limited to, interactions of local political figures, law enforcement, legislation, court system, and other public services. The government system of systems provides for the legal basis for the establishment of the city and all of the city's systems. The government system of systems is the second employer of residents.

2. City Planning

John Levy characterizes city planning, and thus cities, as having the qualities of "interconnectedness and complexity" (Levy 2013). The term interconnectedness is misleading and limiting given the context of the city as a system of systems. Interconnectedness merely infers the existence of a reciprocal relation between objects, which is correct in a city composed of interacting objects (or systems). However, the view of a city as a system of systems requires the city to have functions. Interconnectedness does not infer functions of the aggregated city, therefore, the reciprocity of interactions have no grander purpose than merely to exchange EMMI between the objects of interaction. Therefore, for the purposes of this thesis, city planning is considered to have the qualities of integration and complexity (Levy 2013).

As described in Chapter III, Section B.1, a city is a system of systems, as such, city planning is system architecting. City planning is the merging of city theory (plans, goals, aggregate functions) with physical design (Levy 2013). City planning takes into consideration the needs, benefits, and costs each of the city's systems in order to provide

an integrated design that enables the uninhibited interaction of the city's systems to provide measurable performance of the city as a whole. City planners should not only focus on the interactions of the systems within the city, but with objects and systems external to it. Mechanisms of interaction with entities external to the city are essential to the sustainment of the city and relevance of the city beyond the city's boundaries.

3. History

The first major shift in the U.S. towards urbanization took place in response to the Industrial Revolution in the early to mid-nineteenth century and is illustrated in Figure 5. The technological advancements in tools, equipment, and processes enabled the adoption and implementation of factories. Quick and efficient processes empowered businesses to increase their profit margin, by decreasing the cost and time it took to develop a single product. The decreased production time made mass production feasible. Mass production triggered two events—adoption of the department store and the need to export goods out of the city. Due to the enormous amounts of goods that could now be produced, the small general stores did not have enough room to store all the products. The department store was created to solve this issue. The department store also solved the issue of running out of product to quickly and created a demand for workers. Secondly, mass production provided manufacturers so many products that exporting and importing goods became a solid business (Levy 2013).

At the time, it was rail and water provided low cost transportation and was the ideal method of importing and exporting goods. Access to rail and water ports became critical to the fruition of the city. As a result, cities formed around key water ports and transportation hubs, particularly on the east coast. Rail transit hubs were located nearby the ports to provide quick offload to and from cargo vessels. The port cities quickly became densely populated with businesses and further increased the demand workers, i.e., an increase in the fractal nature of these cities.

Prior to the industrial revolution, the vast majority of Americans were employed on farms. Farmers were low wage employees, who had to live closet to work, especially since personal transit was very expensive. The appeal of rapidly growing urban life and

higher wages influenced many farmers to transition to urban employment, and subsequently urban residence. The speed at which this happened was so rapid, urban residential construction could not keep up with the immigration of workers.

Uncontrolled, rapid urbanization proved to be a major problem for the city. Residences were built to very poor standards and incredibly small. Adequate insulation, plumbing, clean water, waste disposal were often an afterthought. Further, the location of residences was in such proximity to the factories that residents were subjected to continuous and hazardous noise and pollution. Sewage systems were not merely as large as they should have been and did not take advantage of gravity or topography to keep human waste moving. Stagnant refuse posed a significant health issue to city life.

During the first major urbanization of the U.S. there were significant failures to plan. This particular era is plagued by a reactionary mindset. This problem is evident in the rapid construction of residences without the proper coordination with infrastructure. There was a significant need for city planners to identify the city’s capability to support such an influx of workers. More importantly, a city planner would have managed the immigration such that the capabilities to provide food, shelter, and medical would have been evolved at the same rate as that of the immigration. This work is the fundamental function of city planners: to architect and synthesize the systems of interaction within the city, to fulfill the needs of the primary stakeholders: government, constituents, and businesses (Levy 2013).

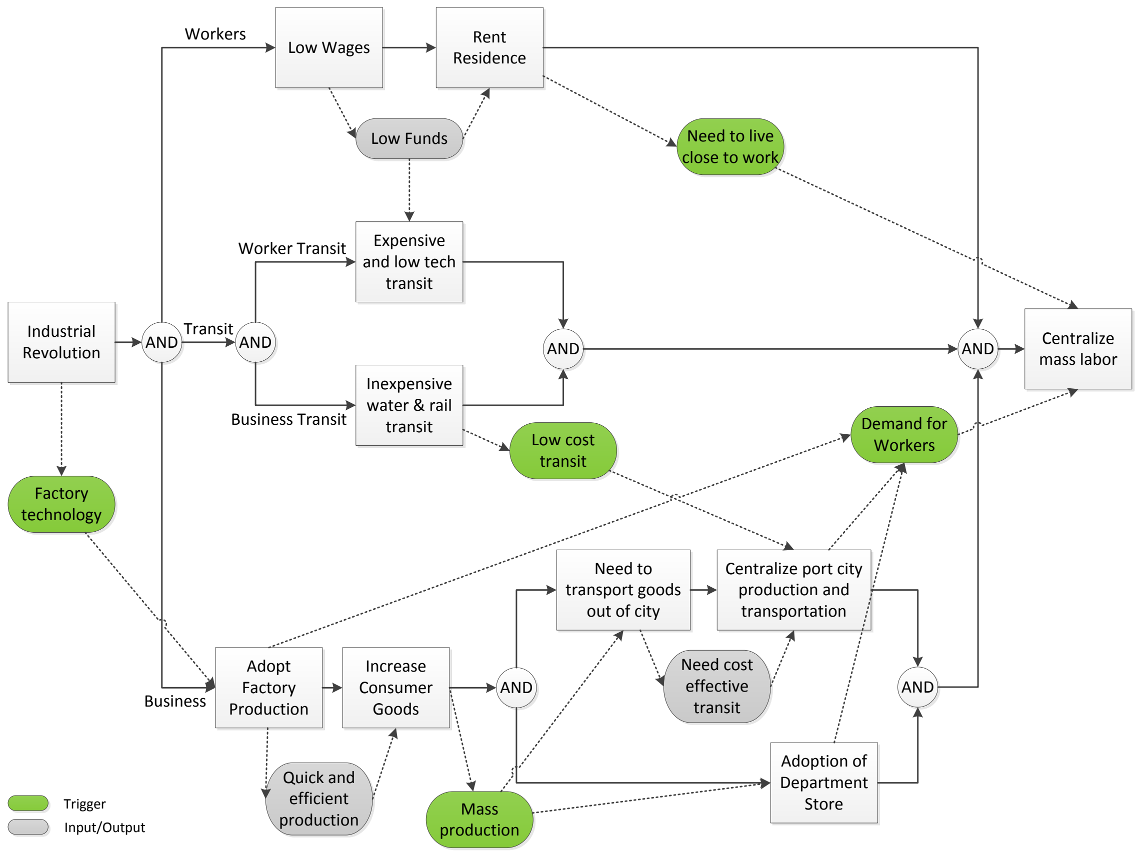

Figure 5. Nineteenth Century Urban Growth Model (after Levy 2013)

The twentieth century experienced quite a different dynamic than the nineteenth century, and is illustrated in Figure 6. By this time, the excitement behind urban expansion and large demand for workers had subsided. Employment was very high and wages were increasing, which provided residents with sufficient finances to acquire a home on a mortgage. Married couples began expanding their family, presenting a new desire for a larger residence. Parents perceived the ideal family life to be housed in much larger home and with a backyard. Automobile equipment and production technology had finally caught up with the industrial revolution, making it more affordable than ever to own a vehicle. With an automobile, a worker could live further away from home and commute in. Highway and parking construction would become critical to sustaining this era of suburbanization. Now, families could become detached from the noise, pollution, over-crowdedness, and disease that urban life had become infamous for in the previous century. Financial stability, affordable personal transportation, the desire for larger

homes, and favorable government policies made suburban life very appealing. Advancements in electronic technology, such as the telephone, reduced the need for face-to-face communication. Since communication no longer had to be in person, people could remain socially connected without the need to live in close proximity to each other. The telephone increased the reach of human interaction well beyond vocal range.

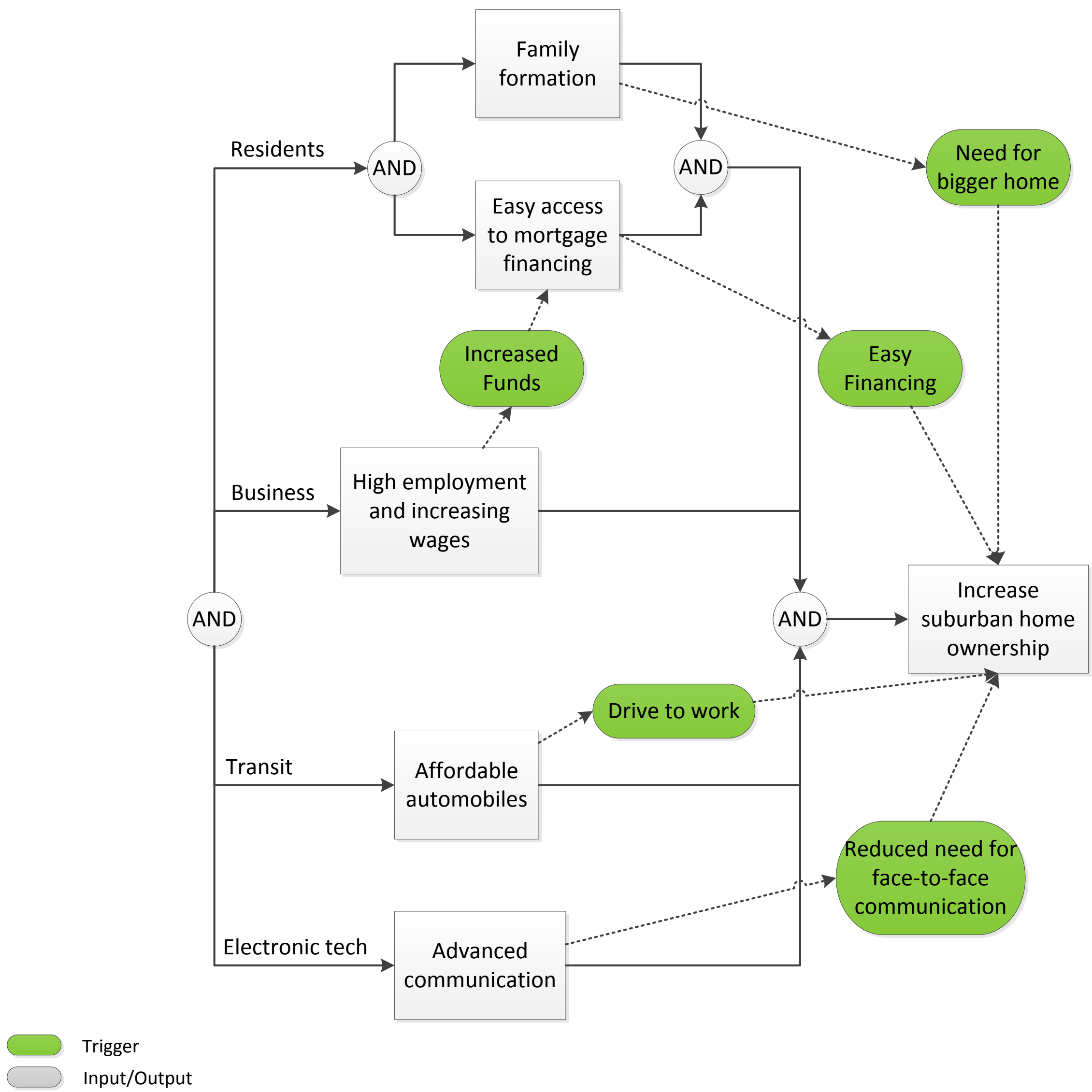

Figure 6. Twentieth Century Suburban Growth Model (after Levy 2013)

The second thing that occurred in the twentieth century was the emergence of residential commuters between suburbs, illustrated in Figure 7. Businesses realized that

there was an enormous opportunity in suburbs. First, the suburbs provided an untapped population of consumers who needed access to groceries, household goods, clothing, and other goods and services. Secondly, the manpower needed to run such suburban businesses already existed in the suburbs. The consequential influx of people was an ideal situation for businesses. Store fronts materialized throughout the suburbs. More interesting is that suburban residents began acquiring work in other nearby suburbs, not the urban center of the city. Suburb-to-suburb transit emerged, and with it an even stronger need for roads and highways.

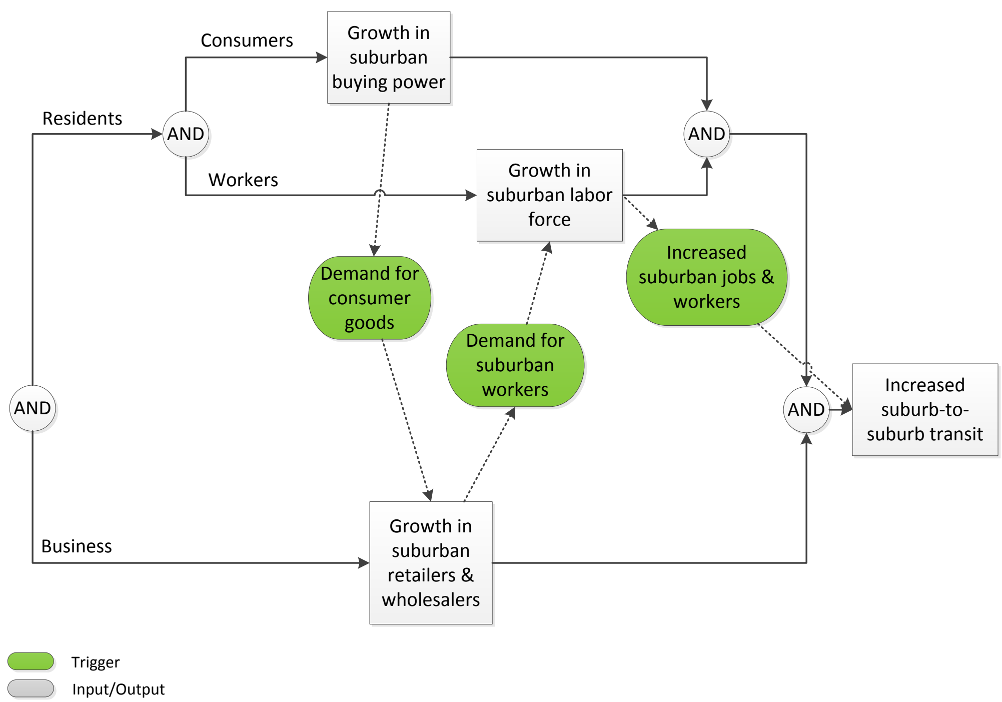

Figure 7. Suburb-to-Suburb Transit Model (after Levy 2013)

The 21st Century birthed the Millennial generation. Within the first decade of life, the Millennials experienced the greatest recession since the Great Depression. News of the housing market crashing, people losing their suburban homes, rising gas prices, and the compounding issues associated with global warming have spread throughout the country. As a result, the Millennials have grown into adulthood with what appears to be a conservative mindset. An environmental consciousness has also emerged among consumers, businesses, and government agencies. Social media and the Internet have

provided users the ability to remain socially connected and create new connections at levels far beyond the telephone and traditional face-to-face. As such, there has been an observed trend in Millennials to favor urban living. Urban environments provide employment, residence, society, groceries, and entertainment options within walking distance. The costs of vehicle ownership are avoided, the pollution of said vehicle is negated, and walking exposes the subject to the interactions of other people creating opportunities for new social relations. Millennials also tend to delay parenthood, which diminishes their need for larger residence. Urban centers such as New York and L.A. maintains such a high tempo and buzz that is attractive to energetic young adults. The onset of mixed use developments within the suburbs will possibly curb some Millennials interest in urban life (Ross 2014).

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IV. MODELING AND SIMULATION

A. FRACTAL MODEL

Batty and Longley introduced a concept of a city as being an aggregate of self-similar forms in the spatial dimension (Batty and Longley 1994). In this sense, city geometric growth is categorized as two types: organic and planned. Organic infers the likeness of cities to spatially evolve to cell growth, moving in conformance with the environment. Organic cities follow the contour of the land. Planned cities force the environment to conform to basic geometric shapes such as straight lines and squares. The overall growth of cities naturally includes a combination of both types, which results in an irregular shape. This irregularity is repeated at every level of aggregation within the city, which makes city spatial growth conform to fractal theory (Batty and Longley 1994). A fractal is "an object whose irregularity as a non-smooth form, is repeated across many scales, and in this sense, systems" (Batty and Longley 1994).

Self-similarity refers to the presence of a fundamental structure of elements which is evident at every level of aggregation (Batty and Longley 1994). This thesis focuses on integrating humans, cities, and the Internet, which goes beyond the spatial dimension of Batty and Longley's theory. This thesis considers self-similarity to encompass the dimensions of behaviors, functions, and objects, i.e., the objective frame in which observations and measurements are made.

A city's fundamental structure of elements is revealed in the basic building block of a city, a housing unit (Batty and Longley 1994). A housing unit, whether it is a detached home or an apartment unit, exhibits the same structure of elements as that of a city— society, environment, and organizations and institutions (Warren 1963 and Blanchard and Fabrycky 2011). The society is evident in the existence of the human occupier(s). The environment refers to the land upon which the home rests, to include ambient temperature, weather, and atmosphere. The existence of organizations and institutions are realized in the tangibility of the home and the presence of household objects such as beds, tables, chairs, and sofas.

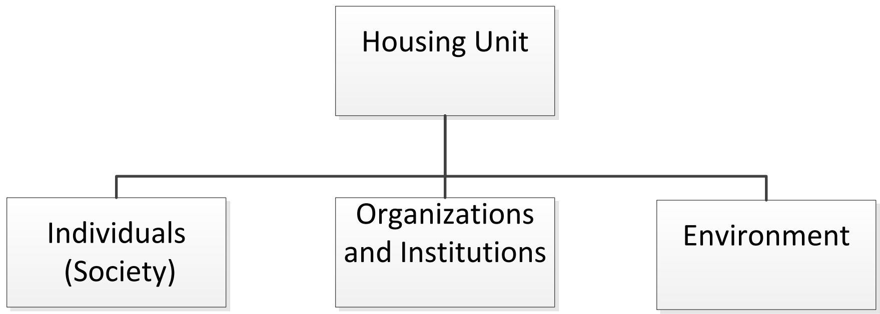

Figure 8. Housing Unit decomposition (after Warren 1963 and Blanchard and Fabrycky 2011)

A business exhibits the same fundamental structure of the housing unit elements. A business is composed of employed personnel (society) who conduct business. The physical structure of the building, computers, telephones, and every other tangible inanimate component of the business is reflective of the organization and institution of the business. The environment is quite simply the localized geographical context in which the business operates.

A governmental agency's branch location is again composed of the same fundamental three elements. The societal element is evident in the existence of government employees at the branch location. The branch's environment is the local geography wherein the physical structure of the government branch resides. The organization and institution element is reflected in the existence of the branch's physical structure and inanimate objects.

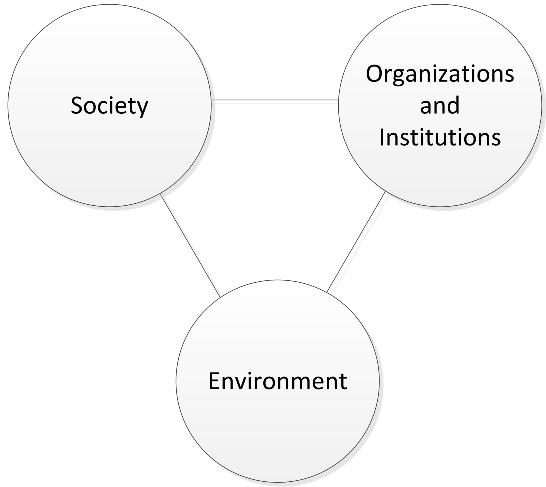

Figure 9. Fundamental Elements of a Fractal City (after Warren 1963 and Blanchard and Fabrycky 2011)

The elements of society, environment, and organizations and institutions (SEO&I) are considered to be the most fundamental and repeatable forms of structure throughout every level of aggregation within a city, state, and country. The interaction of these elements within any system level hierarchy enables the realization of functionality for that system, in the context of a city.

1. Dynamic Modeling

Cities are complex adaptive systems (CAS) in that a city is an "evolving structure" (Holland 1992 and Holland 1995). A CAS has three characteristics: "evolution, aggregate behavior, and anticipation" (Holland 1992). Cities possess the ability to adapt to changes in the environment. As illustrated in Chapter III, Section B.3, cities have evolved (urbanized and suburbanized) in order to adapt to environmental changes such as: technology maturation, economy health, family formation, and job availability to name a few. The section indicated that a city, as a SoS, performs aggregate level functions (production-distribution-consumption, socialization, social control, social participation, and mutual support) through the interactions of the environment, society, and organizations and institutions (Warren 1963 and Blanchard and Fabrycky 2011). These aggregate level functions cannot be realized by any single system, thereby meeting the "aggregate behavior" requirement (Holland 1992). Lastly, activities within cities can

be said to “anticipate,” because they are composed of rational humans. The previous discussions on SET and TRA, Chapter III, Section A.1 and Section A.2, mapped the cognitive processes which relate stimuli to action. By understanding how humans formulate decisions, human action can be anticipated and therefore planned for. City planning departments anticipate and therefore direct the growth of the city. City planning departments are part of the public system of the city, thereby the city anticipates. CASs are difficult to understand and control, use of a system dynamics model will simplify the management and planning of the city SoS (NHS Confederation 2005).

Models are a representation of the relations of objects or processes (Langford 2012), and models are an “abstraction of reality” (Buede 2009). The use of models enables the simplification and understanding of complex systems, in particular social systems (Hannon and Ruth 2001). Early in the design process, models are used to illustrate how a system will accomplish stakeholder needs at a high level of abstraction. Later in the design process, models are used to illustrate the necessary objects, processes, and interactions that must occur in order to realize the desired functionality (Buede 2009). Designers implement “mathematical and physical details of the system” into models to analyze and simulate the real system, without affecting the actual system (Buede 2009). Models are considered to be computer based and executable as a simulation for the purpose of this thesis.

Dynamic models are simulation models, and simulation models are quantitative models. Quantitative models provide numerical outputs. A dynamic model is a type of model whose mathematical variables are time variable (Buede 2009). The uses of dynamic models are studies involving: analysis, feasibility, and control. Analysis seeks to understand the outputs of the system. In an analysis study only the inputs and the system parameters are known or estimated. Feasibility studies aim to understand the system’s ability to deliver a specified output given a particular input. In feasibility studies only the inputs and desired outputs are known or estimated. Control studies determine the level of influence external entities have in relation to providing inputs to the system. In control studies only the system and its outputs are known or estimated, while the inputs are varied (Wismer 1967).

Dynamic modeling is essential for a city composed of fractals which are constantly evolving in organic and planned fashions (Batty and Longley 1994). The uses of dynamic modeling for a fractal city are realized in city planning efforts. For instance, if new construction of a power plant was being contemplated by city officials, a simulation of the effects of the completed project could be very useful in anticipating systemic reactions in: traffic flow, employment, and the economy. Further dynamic modeling, can provide insight to current processes and behaviors, and identify ways to make them more efficient.

2. Standardized Framework

In order for a dynamic model of the city to be created, there first needs to be standardization for how the three fundamental elements interact with each other to enact system functionality. Second, a standard needs to be established for how systems interact with each other. Once a standardized framework is established for the interaction of elements, then a dynamic model can be created for any level of aggregation required.

Chapter IV, Section A established the fundamental elements (SEO&I) whose interactions result in system level functionality. The self-similar structure of these fundamental elements is evident in every level of aggregation in the context of a city. The interaction of these elements at the city SoS level enables the functions of production-distribution-consumption, socialization, social control, social participation, and mutual support (Warren 1963). If the fundamental elements form the most basic fractal of the city, then it follows that the interaction of these elements enables the five functions of a city, in self-similar and repeatable forms, throughout every level of aggregation, in the context of a city. The self-similarity and repeatable nature of functionality describes the functional dimension of the fractal city. That is, every fractal, in the context of a city, has five functions: production-distribution-consumption, socialization, social control, social participation, and mutual support (Warren 1963).

The fractal city exhibits the dimensions of objects, realized in the fundamental elements (SEO&I), and functionality. The dimension of behavior naturally follows as behavior is the corresponding action in direct relation to influential EMMI (Langford

2012). Behavior is manifested in observations of functions or objects, or lack of functions or objects. Essentially, people adjust their behaviors to what they see and do not see. The behavioral dimension of the fractal city is realized in the internal influences and corresponding actions of the fundamental elements within any system, and between systems. If every system within the city SoS has self-similar and repeatable objects and functions, then they also have self-similar and repeatable behaviors. Functions enable the transference of influential EMMI between systems, and enable the response within the system. City fractals (or systems composed of the three fundamental elements) have self-similar and repeatable functions to influence each other through EMMI, and to respond to influential EMMI. Therefore, city fractals have behaviors which are self-similar and repeatable at every level of aggregation in the context of a city.

At the most basic level SEO&I are considered simply objects and not a SoS; interactions are describable first in the physical sense of habitation. Society and O&I independently inhabit the localized environment. The environment exchanges energy in the form of structural support (that is the reciprocated upward force to support downward weight) to both objects (society and O&I). The exchange of energy is also observed in the transfer of light, heat, impact of precipitation, and force of wind. The informational exchanges from the environment, about the environment, occur in the cognitive interpretation of the meaning of received environmental transmissions of energy. External to cognitive interpretation the environment does not exchange information. The environment also does not exchange monetary wealth.

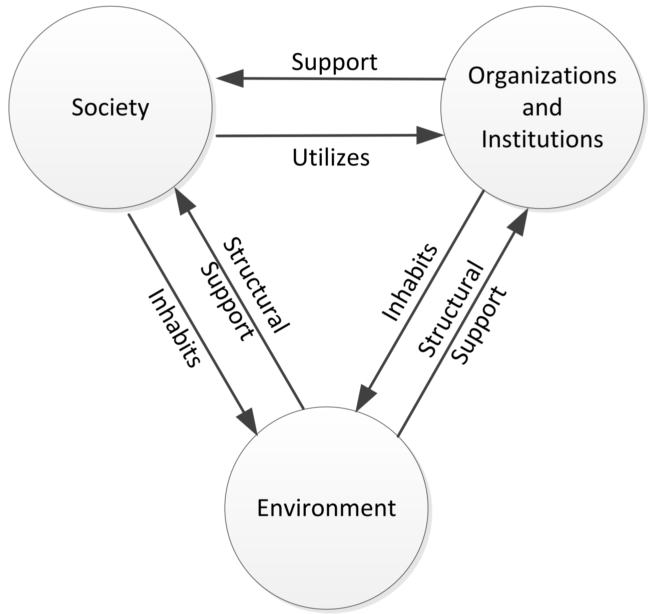

Figure 10. Interactions of SEO&I (after Warren 1963 and Blanchard and Fabrycky 2011)

The environment exchanges matter with society and O&I in a multitude of ways. A fragment of O&I physical structure (piece of wood) may break off and fall into the dirt, embedding itself in the environment. However, the material exchange of importance occurs when society and O&I interact to enact the function of production-distribution-consumption (PDC). The enactment of PDC requires material exchanges with the environment in the form of importing raw materials, such as lumber, from the environment and exporting process waste into the environment. The PDC function is enacted by a process by which society and O&I exchange EMMI. The process is simply the systematic sequence of activities that transforms raw material (input) into a product (output) which is distributable and consumable (Langford 2012).

Considering the material exchanges between the fundamental elements, the society can never exchange a material human object (a single person) with either of the remaining fundamental elements (environment and O&I). That is, a person cannot become part of the O&I element, but instead, the person must remain a separate entity within the social element. Persons may only interact with O&I. In the case of the environment, the person becomes part of the environment only when they die, which is

outside the scope of inquiry. However, in the case of a manufacturing and distribution company there is a society operating within the physical boundary of the company's physical location. This instance does not describe a material exchange of human objects with the O&I element of the manufacturing company. The manufacturing company is a fractal, in the context of a city, having the interacting elements of SEO&I. The physical structure of the company resides in the O&I element at the highest level of hierarchy, of the company, which includes the aggregation of all employees (society), all environment, and all structures (O&I) in the context of the company. The elements of interaction enacting the function of production, within the bounds of the company's physical structure, belong to a subservient fractal— the production department within the company. The production department fractal, in the context of a city, exhibits the three fundamental elements of SEO&I. Society is observed in the existence and assignment of employees to the production department. O&I is realized in the equipment, tools, and facilities which the employees utilize to produce the product. The environment is exhibited in the air, humidity, temperature, and other naturally occurring environmental elements within the boundaries of the production department.

Informational exchanges occur between the society and O&I, but only because O&I is a medium of information transfer. O&I is never an originator of information. The origin of information resides in the rational entity which derived the information. O&I only receives and transmits information, which necessitates the involvement of a society at both ends of the exchange. This interaction does not necessarily mean that an individual is present at the time of information exchange. Computer processes can be automatic, such as a webpage. However, the presentation of information from the webpage required information to be programmed by an individual at some time. Absent of time, both individuals, programmer and webpage visitor, acting in independent fractals (home and business) directly exchange information through the communication infrastructure. The interaction between the society and O&I within each fractal of Home and Business cause an interaction between the fractals themselves.

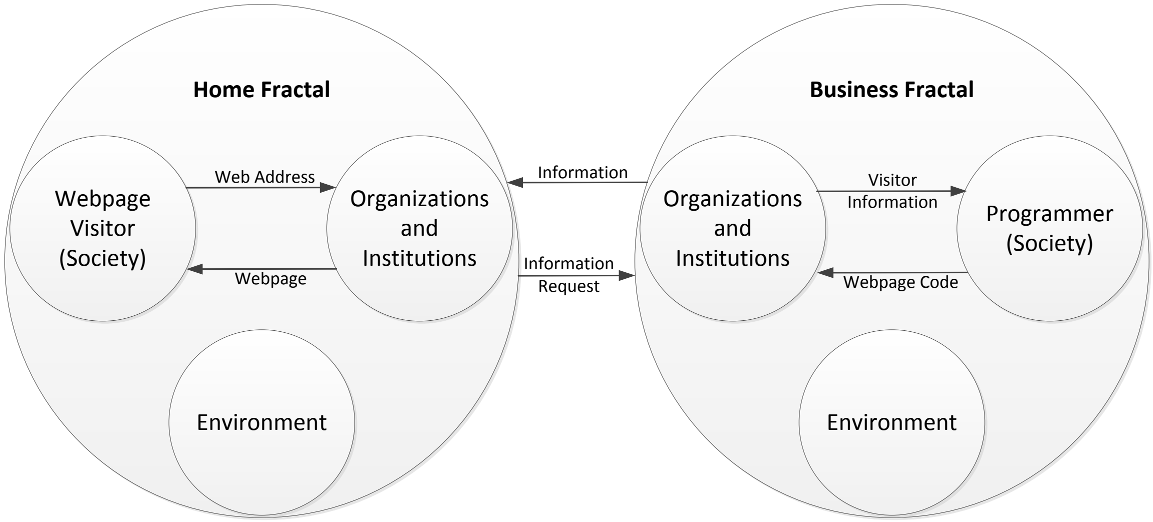

Figure 11. Communication Infrastructure Interaction Between Fractals

The process by which O&I exchanges information may include storage, manipulation, amplification, or degradation. The primary component of O&I involved in information exchange is the communication infrastructure, to include: telephones, computers, mobile technology, and the Internet. The element of O&I provides each fractal a very important interface for interactions with other fractals.

Informational exchanges also occur between societies of separate fractals, separate from O&I. Such societies communicate aurally, visually, and by touch. Naturally, aural and visual interactions between individuals require a medium through which energy (sound and light) is transferred, the environment. Because the environment does not rely upon an intricate organization of manmade objects, such as the Internet, and assuming terrestrial based communication, aural and visual interactions between separate societies are modeled without environmental interactions.

As discussed in Chapter III, Sections A.1 and A.2, informational exchanges between fractals, particularly the element of society, have the ability to act as stimuli for action. The realization of action, based on stimuli, is behavior (Langford 2012), and as such, fractals have the ability to influence behaviors of other fractals. Stimuli are not merely restricted to that of information, but of energy, matter, and material wealth. The output of any fractal has the potential to solicit behavior of another fractal, as long as the

second fractal receives as an input, the output of the first. A city's behavior, as an aggregation of fractals interacting in behavioral relationships, is then the product of the interactions of all subservient city fractals.

Fractal interaction occurs through the exchange of EMMI, just as the three fundamental elements interact. A fractal's output is determined by the process of interactions of SEO&I within the subject fractal. The subject fractal's inputs are determined by the process of interactions of SEO&I within a separate fractal. A home fractal, specifically the O&I pertaining to the physical structure of the house, receives electrical power as an input. The process of producing electrical power and exporting it is enacted within a separate fractal, the electric company. However, as shown above, cities are composed of fractals interacting in behavioral relationships. The electric company does not simply provide electrical power to every fractal within the city. Operating within the definition of a behavioral relationship, the electric company requires a stimulus to provide power— an initial request for power and the monthly exchange of monetary wealth. In similar fashion do all fractals of the city interact based on behavioral relationships, one stimulating the other to act.

B. OUTPUTS AND IMPLICATIONS

The implications of such a city model based on aggregated fractals, with behavioral relationships, is the ability to identify behavioral trends, develop measures of effectiveness (MOE), and simulate modifications at any level of city aggregation. Further, city fractal models can be utilized to assess and forecast behavioral relationships between cities, states, and nations. The assignment of MOEs can aid in identifying areas within the city whose processes of interactions need adjustment. MOEs can be prioritized, making it clear to government officials which problems need to be addressed first. An executable model, or simulation, can forecast the systemic effects of fixing problems identified through the use of MOEs. Simulations are also very useful in "what-if" analysis, through which the effects of city modifications, natural disaster, reorganization, policy changes, and the like can be assessed prior to these issues becoming reality. The development of an executable fractal city model and MOEs can

enable cities to become much more efficient in productivity, fixing problems, and planning for the future.

Each fractal outputs some form of quantifiable EMMI. The society element provides a fractal-level output in the form of energy, monetary wealth, information, and matter. In the sense of energy, the society element interacts with other fractals in the sense of visual, audible, and tangible forms of energy. In interactions between societal members of different fractals, such as in public spaces, individuals exchange energy and information in casual conversation. Such an interaction is also observed in a store, where a consumer converses with an employee. A consumer purchasing a product is an example of the exchange of every component of EMMI, in the sense that these exchanges involve: product information, the tangible product, payment, and the energy which transmits product information from the point-of-sale (POS) monitor to the consumer. MOEs for this example would be the number of similar products purchased that day, how much consumers spend each day, and the number of transactions occurred at each POS terminal.

O&I transmits energy and information at the fractal-level through computer networks (Internet), telephone systems, radio frequency, visual communications, and audible advertisements. A business fractal may have a billboard (O&I) which transmits energy (light) and information towards pedestrians and vehicles. A MOE for the billboard may be the number of customers received per billboard (or stimulus). O&I exchanges matter in the form of a tangible product to a separate fractal. For instance, a snack machine, a component of a business fractal, exchanges matter in the form of a candy bar with an individual who is part of a consumer fractal. An MOE for this transaction is the number of each kind of bar sold and time of sale.

The MOEs identified provide insight into the productivity of the interactions of the subjected fractals. A fractal pertaining to a certain geographical location, or demographic, can be derived from a combination of sub-fractals. That is a particular business fractal can be divided into sub-fractals focused on certain consumer characteristics, giving the business executives the ability to evaluate the business' performance in different markets.

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V. CONCLUSION

The research indicates that the use of fractals in decomposing cities can be useful in assessing the city's performance, identifying problematic areas, hypothesizing and simulating modifications, and forecasting future performance. Through the lens of a fractal model, a city or a ship can be analyzed and evaluated against measures of effectiveness to help discern how to better utilize physical structures and human activities to create a more effective and efficient environment through new types and frequencies of interactions. Within the context of a city, that interaction can motivate businesses to market and sell directly to passersby. With the context of a ship, that interaction can assist in identifying design and architectural features that will improve operations, readiness, emergency handling, and mission accomplishment with smaller crew size. The integrative framework affords a means to develop measures of effectiveness. The social theories provide a necessary foundation to understanding the aggregation of behavioral patterns within the city, as the city is primarily a societal construct.

More research is needed to collect data of fractal interactions, integrating the data into an executable model, and developing standardized specifications for the model. Data collection methodologies also need to be researched to enable quicker collection and analysis timelines. Faster data collection and analysis may be supported by utilizing mobile technology to track consumer behaviors and identify causal stimuli such as: weather, geographic location, time of day, recent behavior activity, and seasons. The use of this type of data will affect business models and marketing strategies, which should also be addressed. Lastly, research is greatly needed to identify how consumer behavior is altered through mobile technology, and the reciprocating needs of the consumer upon mobile technology to further enable behavioral change.

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